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**Detailed temporal modelling of carbon and
water fluxes from pastures in New Zealand:
Case study of an experimental dairy farm in
the Waikato region**

**A thesis presented in partial fulfilment of the
Requirements for the degree of**

Doctor of Philosophy

In

Soil Science

Massey University, Palmerston North, New Zealand

Nicolas Puche

2017

ABSTRACT

The terrestrial biosphere is an important pool of carbon, with its size governed by the opposing processes of CO₂ uptake through photosynthesis and release through respiration. It is therefore critically important to understand and reliably and accurately model these processes and predict changes in carbon exchange in response to key drivers. Pasture-based livestock production is particularly important for the New Zealand's economy but it is also a main contributor to NZ's greenhouse gas budget. My Ph.D. work used half-hourly eddy-covariance (EC) data, previously collected over 2 consecutive years from a grazed pasture in the Waikato region. The main aims of this study were to assess whether there was any bias in gap-filled eddy covariance measurements, to assess whether incomplete capture of cow respiration during grazing events could have led to biased observations, and to quantify the resulting difference on the net carbon budget of the farm. I approached the work by developing a new process-based model, CenW_HH, running at a half-hourly time step, to predict the energy and CO₂ exchange of grazed pastures. I implemented and evaluated different photosynthesis models and upscaling schemes and modelled the energy budget separately for the canopy, litter layer, and the soil. CenW_HH was then parameterised and validated with the available EC measurements. The paddocks surrounding the EC tower were rotationally grazed, which caused heterogeneities in respiratory pulses when grazing events were in the flux footprint and subsequent vegetation cover on the different paddocks. To deal with that heterogeneity, the model was run independently for each individual paddock and a footprint model was used to estimate resultant net fluxes at the EC tower. Modelled fluxes agreed well with half-hourly observed fluxes as seen by model efficiencies of 0.81 for net ecosystem productivity, 0.75 for gross primary production, 0.70 for ecosystem respiration, 0.87 for latent heat flux, 0.76 for sensible heat flux, 0.94 for net radiation, and 0.92 for soil temperature. CenW_HH was then used to test for any biases in gap-filled data for times without the presence of grazing animals, but identified no consistent systematic deviations. Eddy covariance measurements often failed to capture carbon losses due to cattle respiration, especially when measurements had to rely on gap-filled data. By replacing gap-filled NEP fluxes affected by grazing cattle by estimates generated by CenW_HH, the farm carbon budget was reduced by 31% and 113% (and turning from a positive into a slight negative balance) in 2008 and 2009, respectively.

ACKNOWLEDGEMENTS

Firstly, I would like to express my sincere gratitude to my advisor Doctor. Miko Kirschbaum for the continuous support during my Ph.D., for his patience, motivation and immense knowledge on many different topics and for the talks that we had. His feedbacks and guidance helped me at all steps of this research project and on the writing of the thesis and I could not imagine having done it without such a great supervisor.

My sincere thanks also go to Professor. Mike Hedley for his guidance and useful insights and suggestions. I am grateful that despite his busy schedule he was always able to meet me at short notice and for going through and making comments and suggestions that improved drafts of my thesis.

I also thank Associate Professor Marta Camps Arbestain for accepting to be one of my co-supervisor and for organising the “journal club” sessions in which most of the presentations and discussions were far away of my research project but widened my view on soil science in general.

I am thankful to my other co-supervisors, Professor Louis Schipper and Doctor Michael Dodd for being part of my Ph.D. advisory panel and for providing the data that were needed to accomplish this project.

I am grateful to the NZAGRC (New Zealand Agricultural Greenhouse Research Centre) for providing me the funding to complete my Ph.D. and to Landcare Research for accepting me to use their facilities; this was an awesome place to work with kind and brilliant persons.

A big thanks also goes to all friends and persons that encouraged me pursue my studies towards the completion of this thesis, without your encouragements this would have not been possible.

And last but not least, I would like to thank my family and family in law for their support and understanding during all stages of my Ph.D. and specially my wife Justine which followed me abroad for 4 years, I am very grateful for your support during hard times, for your patience and for all the good time we had.

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LIST OF ABBREVIATIONS

| | |
|-------------------|--|
| NH_4^+ | Ammonium |
| NO_3^- | Nitrate |
| °C | Degree Celsius |
| A | Instantaneous single leaf photosynthesis |
| A/PPFD | Photosynthesis light response curves |
| A_c | Daily canopy net CO ₂ assimilation rate |
| ADP | Adenosine Di-Phosphate |
| AGC | Automated gain control |
| ATP | Adenosine Tri-Phosphate |
| BL | Big-leaf upscaling scheme |
| C | Carbon |
| CH ₄ | Methane |
| CO ₂ | Carbon dioxide |
| EC | Eddy-covariance |
| ER | Ecosystem respiration |
| ET | Evapotranspiration |
| FvCB | Farquhar et al. (1980) photosynthesis model |
| G | Soil heat flux |
| GCM | Global climate models |
| GHG | Greenhouse gas |
| GPP | Gross primary production |
| H | Sensible heat flux |
| H ₂ O | Water |
| IPCC | Intergovernmental Panel for Climate Change |
| IRGA | Infrared gas analyser |
| LAI | Leaf area index |
| LE | Latent energy flux |
| LSM | Land surface model |
| LUC | Land use change |
| LUE | Light use efficiency |
| MBE | Mean bias error |
| N | Nitrogen |
| N ₂ O | Nitrous oxide |
| NADP ⁺ | Nicotinamide Adenine Dinucleotide Phosphate |
| NADPH | Nicotinamide Adenine Dinucleotide Phosphate Hydrogen |
| NECB | Net ecosystem carbon balance |
| NEE | Net ecosystem exchange |
| NEP | Net ecosystem production |
| NOAA | National oceanic and atmospheric organisation |
| NPP | Net primary production |
| NRHC | Non-rectangular hyperbolic curve |
| NSE | Nash-Sutcliffe criteria or model efficiency |
| NZ | New Zealand |
| OM | Organic matter |
| P | Phosphorus |
| P | Energy flux associated with photosynthesis |
| PFT | Plant functional type |
| PKE | Palm kernel expeller |
| PPFD | Photosynthetic photon flux density |

| | |
|------------|--|
| ppm | Part per million |
| PR | Photorespiration |
| PS | Photosynthesis |
| r^2 | Coefficient of determination |
| R_a | Autotrophic respiration |
| R_q | Growth respiration |
| R_h | Heterotrophic respiration |
| RH | Atmospheric relative humidity |
| RHC | Rectangular hyperbolic curve |
| R_m | Maintenance respiration |
| RMSE | Root mean squared error |
| R_n | Net radiation |
| RuBP | Ribulose 1.5-bisphosphate |
| SG 90 | Shuttleworth and Gurney (1990) model |
| SOC | Soil organic carbon |
| SOM | Soil organic matter |
| SS | Sun/shade canopy integration scheme |
| SVA | Soil-vegetation-atmosphere |
| SVAT | Soil-vegetation-atmosphere-transfer model |
| SW 85 | Shuttleworth and Wallace (1985) modelling scheme |
| Tac 86 | Taconet et al. (1986) model |
| TPU | Triose phosphate utilisation |
| T_{soil} | Soil temperature |
| VPD | Vapour pressure deficit |
| WUE | Water use efficiency |
| ΔS | Heat storage of the vegetation canopy |